

UNITED STATES PATENT APPLICATION

For

Microstrip-Waveguide Transition

By

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**Attorney Docket No. 017750-584
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BACKGROUND

FIELD OF INVENTION

[0001] The present device relates generally to the interconnection of components for the transmission of electromagnetic energy. More specifically, the device relates to a transition for interconnecting a microstrip and a waveguide.

BACKGROUND INFORMATION

[0002] A microstrip-waveguide transition is an apparatus for the transmission of electromagnetic energy between a microstrip transmission line and a waveguide. Present microstrip-waveguide transitions can take several forms. For example, the microstrip can be inserted perpendicularly into an opening within a wall of the waveguide, the microstrip can be inserted collinearly into the open end of the waveguide, or the waveguide can be mounted perpendicularly to the microstrip ground plane.

[0003] These basic forms are suitable for most applications of a transition. However, there remain applications where the basic forms are not used due to space constraints and performance requirements. For example, in a phased array having multiple waveguide ports, the available space limits the dimensions of the microstrip-waveguide transition. In addition, some applications require a hermetic seal between the microstrip and the waveguide. Current microstrip-waveguide transitions can be labor intensive to construct due, for example, to alignment needs of numerous parts in the current microstrip-waveguide transitions. For larger millimeter wave phased array systems (e.g., those having thousands of waveguide ports), the labor cost can become impractical. Even with modern automated assembly

equipment, the construction time is affected by need for alignment in the interconnect systems used today.

SUMMARY OF THE INVENTION

[0004] Exemplary embodiments are directed to a microstrip-waveguide transition for transmission of electromagnetic energy including a waveguide having an open end, a dielectric substrate attached to the open end, a microstrip probe on the dielectric substrate, wherein a capacitive susceptance across the open end when the open end is exposed to electromagnetic energy, and a means for countering the capacitive susceptance with inductive susceptance.

[0005] Exemplary embodiments are also directed to a microstrip-waveguide transition including a waveguide having an open end, a dielectric substrate having a first side surface attached to the open end, two separated conductive plates on the first side surface, and a microstrip probe on a second side surface of the dielectric substrate.

[0006] Exemplary embodiments are also directed to a microstrip-waveguide transition including a waveguide having an open end, a dielectric substrate having a first side surface attached to the open end, a microstrip probe on a second side surface of the dielectric substrate, a backshort cap attached to the second side surface, and wherein the backshort cap has a central portion at a height in relation to the microstrip probe that is less than $1/2$ of a wavelength for a frequency at which the microstrip-waveguide transition operates.

[0007] Exemplary embodiments are also directed to a microstrip-waveguide transition including a waveguide having an open end, a dielectric substrate having a first side surface

attached to the open end, a microstrip probe on a second side surface of the dielectric substrate, a backshort cap attached to the second side surface, and wherein corners of the waveguide, dielectric substrate and backshort cap are in alignment.

BRIEF DESCRIPTION OF THE DRAWINGS

[0008] Other objects and advantages of the present invention will become apparent to those skilled in the art upon reading the following detailed description of exemplary embodiments, in conjunction with the drawings of the exemplary embodiments.

[0009] Fig. 1 is an exploded perspective view of an exemplary embodiment of the invention.

[0010] Fig. 2 is another exploded perspective view of an exemplary embodiment of the invention.

[0011] Fig. 3 is an assembled cross-sectional view of an exemplary embodiment of the invention along a line similar to line A-A' shown in Fig. 1.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

[0012] As shown in the exploded perspective view of the exemplary embodiment in Fig. 1, a microstrip-waveguide transition 100 includes a waveguide 102 with an open end 104, which, for example, can be a half-height waveguide opening, a full-height waveguide opening or any other suitable opening size. The open end 104 of the waveguide 102 is attached to a dielectric substrate 106. The microstrip-waveguide transition 100 includes a microstrip 108 and a microstrip probe 110 positioned on a side surface 106a of the dielectric substrate 106 opposite to the side surface of the dielectric substrate on which the waveguide

102 is attached. The microstrip-waveguide transition 100 also includes a microstrip ground on the side surface of the dielectric substrate on which the waveguide 102 is attached. The dielectric substrate 106 above the open end 104 of the waveguide 102 presents a capacitive susceptance across the open end 104 of the waveguide 102 when the open end is exposed to electromagnetic energy. Such a capacitive susceptance can interfere with the transmission of electromagnetic energy between the microstrip 108 and the waveguide 102 so as to cause losses that are unacceptable. Therefore, a means of countering the effect of the capacitive susceptance with inductive susceptance can be utilized to minimize or eliminate the effect of the capacitive susceptance on the transmission of the electromagnetic energy to an amount that will enable use of the microstrip-waveguide transition for an intended application.

[0013] As shown by the dashed vertical lines in Fig. 1, the waveguide 102, dielectric substrate 106 and backshort cap 118 can be aligned. For example, the corners of the waveguide 102 are aligned with the corners of the backshort cap 118, with the corners of the dielectric substrate 106 arranged between the backshort cap 118 and the dielectric substrate during assembly of the microstrip-waveguide transition 100. The corners of the dielectric substrate 110 can be aligned to rest on a flush or recessed surface of the open end 102 of the waveguide 118 or the either the backshort cap 118 or the open end 102. Therefore, corners of the waveguide 102, dielectric substrate 110 and backshort cap 118 of the microstrip-waveguide 100 will be in alignment.

[0014] As shown in Fig. 1, the dielectric substrate 110 completely covers the open end 104 of the waveguide 102 to form a hermetic barrier between the microstrip 108 and the waveguide 102. The dielectric substrate 110 can comprise a single layer of dielectric

material, for example, alumina, insulating polymers or any other insulating material. In the alternative, the dielectric substrate 110 can comprise multiple layers of different dielectric materials. For example, the dielectric substrate 110 can be two layers of silicon dioxide sandwiching a layer of silicon nitride (e.g., oxide-nitride-oxide) or multiple layers of any other suitable insulating materials. The dielectric substrate should have a thickness of 5 to 100 mils or any other thickness sufficient to form the hermetic barrier and/or support the microstrip 108.

[0015] The microstrip 108, as shown in Fig. 1, can have other features that enhance performance characteristics of the microstrip-waveguide transition. For example, double-tuning stubs 114a and 114b can be added to increase the frequency bandwidth at which the microstrip-waveguide transition operates. In addition or in the alternative, an impedance transformer 109 can be used to adjust the impedance level. In addition, an open-circuit stub 112 can be used to make small adjustments to the impedance level. Other types of bandwidth and tuning structures can also be used.

[0016] At least a portion of the capacitive susceptance across the open end of a waveguide can be countered with two separated conductive plates on the side surface of the dielectric substrate attached to the waveguide. As shown in the exemplary embodiment of Fig. 2, a microstrip-waveguide-transition 200 can have a first conductive plate 216a and a second conductive plate 216b that are separated by an opening 217. The first conductive plate 216a and a second conductive plate 216b are formed on the side surface 206b of the dielectric substrate 206 that attaches to the waveguide 202. The opening 217 between the two separated conductive plates 216a/216b acts as an iris for the waveguide 202 when the

waveguide 202 is attached. The microstrip probe 210 on the other side of the dielectric substrate is substantially centered with respect to the opening 217, as shown in Fig. 2. An inductive susceptance is created based upon the width of the opening 217 of the iris for the waveguide 202 in relation to the microstrip probe 210 that counters at least a portion of the capacitive susceptance across the open end 204. The microstrip-waveguide transition 200 also includes a microstrip ground 211 formed on the side surface of the dielectric substrate on which the waveguide 202 is attached. The microstrip ground 211 covers the portion of the surface of the dielectric substrate opposite the microstrip 208 but leaves the surface of the dielectric substrate opposite the microstrip probe 210 uncovered (e.g., at the opening 217).

[0017] The exemplary embodiment of Fig. 2 illustrates the interior surface of a backshort cap 218. Because the backshort cap 218 is hollow, a central portion 220 (i.e., the interior surface of the backshort cap directly under the microstrip probe) of the backshort cap is directly above the other side of the dielectric substrate 206. The peripheral walls 222 of the backshort cap 218 are attached to the other side surface of the dielectric substrate 206 with an adhesive to form a hermetic seal between the backshort cap 218 and the dielectric substrate 206. The adhesive can be a conductive adhesive such as solder, conductive epoxy or any other materials suitable as a conductive adhesive. Furthermore, the microstrip ground 211 is conductively connected to the open end of the waveguide 202.

[0018] At least a portion of the capacitive susceptance across the open end of a waveguide can be countered with a backshort cap attached to the side surface of the dielectric substrate on which the microstrip is positioned. As shown in the exemplary embodiment of Fig. 3, a waveguide-transition 300 can have a backshort cap 318 that has a central portion 320

at a height H in relation to the microstrip probe 310. The backshort cap 318 is formed of a conductive material. The height H should be less than $1/2$ of a wavelength for a frequency at which the microstrip-waveguide transition operates. An inductive susceptance is created based upon the height H of a central portion of an interior surface of the backshort cap 318 in relation to the microstrip probe 310. The inductive susceptance from the backshort cap can be substantially equivalent (e.g., 10% difference) to the inductive susceptance from the two separated conductive plates. Both of these susceptances together can counter or tune out the capacitive susceptance across the open end due to the microstrip.

[0019] The open end of the waveguide 302 in the exemplary embodiment of Fig. 3 is attached to the backshort cap 318 with solder, conductive epoxy or any other suitable conductive adhesive 324. The backshort cap 318 can also be attached to the dielectric substrate 306. As shown in Fig. 3, the conductive adhesive 324 is also in contact with the separated conductive plates 316a and 316b that form the iris for the waveguide 302. In an alternative, the separated conductive plates 316a and 316b could be formed independently from the dielectric substrate and be attached to the open end of the waveguide. Then, the backshort cap would be attached by a conductive adhesive to both the separated conductive plates and the open end of the waveguide.

[0020] Although the present invention has been described in connection with preferred embodiments thereof, it will be appreciated by those skilled in the art that additions, deletions, modifications, and substitutions not specifically described may be made without a departure from the spirit and scope of the invention as defined in the appended claims.